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RUBBER LABORATORY

MARE ISLAND NAVAL SHIPYARD

TECHNICAL REPORT

VIBRATION DAMPING TREATMENTS FOR NEW CONSTRUCTION SUBMARINES
PROGRESS REPORT NO. 11

Project No. S-F013-13-01
Task No. 908
Identification No. 1-0908-1

REPORT NO. 94-37

23 March 1962

ABSTRACT

This work is a continuation of the investigation of vibration damping treatments for thick plates of submarines. It was shown previously that the damping of steel bars by treatments, each of which consisted of a constrained layer of chromated felt and a constraining layer of aluminum, exhibited a maximum at about 75° to 85°F. Damping fell off sharply at temperatures below or above this range. The objectives of this work were to determine the cause of this behavior, and to find other types of treatments yielding satisfactory damping in the temperature range of 35° to 120°F.

It was found that the effect of temperature on the damping of the treatments utilizing chromated felt was due to the materials which were incorporated in the felt, rather than to the felt proper.

Two unconstrained treatments were tested on 3/4 inch and 1-3/4 inch thick steel bars. One of these treatments, Type H, was a nitrile rubber vulcanizate. The other treatment was a plastic compound, the main ingredient of which was a modified polyvinyl acetate.

Higher average dampings over the frequency range between 50 and 2000 cps were obtained at 85°F with two constrained chromated felt treatments, of a weight ratio of treatment to steel of 0.25, than with the two types of unconstrained treatments of 0.25 or 0.30 weight ratios. It was concluded that the two unconstrained treatments tried were not as satisfactory as the constrained felt treatments for damping thick plates on submarines.

REFERENCES

(a) BUSHIPS ltr F013-13-01 Ser 634C1-736 of 21 Jul 1961

(b) BUSHIPS ltr F013-13-01 Ser 634C1-1277 of 15 Dec 1961

(c) BUSHIPS ltr F013-13-01 Ser 634C1-28 of 5 Feb 1962

(d) BUSHIPS ltr F013-13-01 Ser 634C1-162 of 9 Feb 1962

(e) Military Specification MIL-G-20241B of 26 Jan 1953: "Gasket Material, Wool Felt, Impregnated, Adhesive, Pressure-Sensitive (Symbol 2291)"

(f) NAVSHIPYD MARE ltr 10320 (392-6741) of 2 Jan 1962

INTRODUCTION

1. This work is a continuation of the investigation of damping treatments for heavy plates of new construction submarines which was authorized by the Bureau of Ships in reference (a) and amended by references (b) and (c). The previous phases of the investigation were described in Rubber Laboratory Reports, Nos. 94-12, -22, -23, -24, -25, -27, -29, -33, and -36.

2. The present work deals principally with the specific aspects of the problem which were authorized by the Bureau in paragraph 1a of reference (b), namely, the effect of temperature on damping of 3/4 inch and 1-3/4 inch thick steel bars by constrained felt treatments. In addition, the damping of these bars by two unconstrained treatments, namely, Type H, and a treatment consisting of a modified polyvinyl acetate compound were also studied. The last mentioned phase of the investigation was completed prior to receipt of reference (d), in which the Bureau requested that the study of the Type H treatment be held in abeyance pending further information concerning the program.

3. Encouraging results were obtained in previous work at 75° and 85°F with damping treatments based on constrained chromated felt conforming to specification MIL-G-20241B, reference (e). Subsequent data, however, showed that the damping by this type of treatment fell off sharply below and above this narrow temperature range (Report No. 94-36). Damping at 35° and 120°F was found to be only about 1/5 to 1/4 of the damping at 75°F in the frequency band of 50 - 2000 cps. This behavior was considered to be an undesirable feature of the treatments, as was indicated in reference (f). One of the objectives of the present study was to ascertain the cause of the temperature sensitivity of the treatments, with the hope that knowledge of the cause of the undesirable characteristic of the felt might assist in remedying the objectionable feature.

4. It was indicated in Report 94-36 that the pronounced temperature sensitivity of the above treatments probably resided in the constrained chromated felt and not in the constraining aluminum layer. The chromated felt used in the previous phases of the investigation was impregnated with an organic compound. It was also coated on one side with a thin layer of a polymeric adhesive. When a constraining pressure was applied to the chromated felt, the adhesive was forced into the interstices of the felt. One objective of this investigation was to determine whether the temperature sensitivity of the treatments was due to the felt proper, or to the compounds incorporated in it. If the latter proved to be the case, then impregnation of the felt with the proper compounds might improve its damping at temperatures below and above 75° to 85°F.

5. The second objective of this work was to find a satisfactory alternative treatment for the constrained felt type treatment in the event that the felt treatment would not be amenable to improvement. This was the purpose of the tests of the two unconstrained treatments, which were mentioned in

paragraph 2. These treatments were selected for the present study because they had shown promise in the damping of thin steel plates, 3/8 inch thick.

6. This investigation has in the past been aimed at the damping of pressure bulkheads and deep frames, which have flat surfaces for easy application of the treatment. Although the damping of the pressure hull of a submarine is desirable, it is difficult to fit the metal outer layer of a constrained-layer damping treatment to the concave hull surface. If an efficient unconstrained damping treatment could be found for heavy plates, it would perhaps make economically feasible the damping of submarine hulls as well as bulkheads and deep frames.

DESCRIPTION OF DAMPING TREATMENTS

7. The tested treatments are described in detail in Appendices 1 and 2. Appendix 1 lists the treatments which were applied to 3/4 inch thick steel bars; Appendix 2 lists those which were applied to 1-3/4 inch thick steel bars.

8. The treatment used as a control in the experiments with the 3/4 inch bars was Treatment 200. That used as a control in the experiments with the 1-3/4 inch bars was Treatment 198. These treatments utilized a constrained layer of chromated felt, which conformed to reference (e), and a constraining layer of aluminum. They are the best treatments developed to date for these thicknesses of steel plate in view of the requirement that the treatment shall not weigh more than 25% of the plate being damped.

9. Treatment 218 was prepared to find whether or not the damping efficiency of Treatment 200 was dependent on the absorbed polymeric material in the felt

layer. Treatment 218 was identical with Treatment 200 except that Treatment 218 utilized felt with no absorbed polymeric material. The nontreated felt was obtained from the same source as the treated felt, and was the type used by the manufacturer when preparing the treated felt.

10. Treatments 212, 213 and 214 were prepared to find how efficiently unconstrained layers of Type H material would dampen vibrations in 3/4 inch bars. Treatments 204, 205, 206 and 207 were unconstrained layers of Type H material applied to 1-3/4 inch bars. Type H material, based on nitrile rubber, was originally developed to dampen vibrations in 3/8 inch thick steel plates. The recipe for this material is given in Appendix 3. It was vulcanized in the form of 0.63 inch thick slabs which were cross V-grooved with a spacing of 1/2 inch between center lines of parallel grooves. The grooves were 0.33 inch deep.

11. Treatments 215, 216 and 217 were unconstrained layers of Compound 384-578 applied to 3/4 inch bars. Treatments 208, 209, 210 and 211 were unconstrained layers of Compound 384-578 applied to 1-3/4 inch bars. Compound 384-578, based on a modified polyvinyl acetate, was also originally developed for damping 3/8 inch plates. The recipe for this thermoplastic material is given in Appendix 3. It was formed into slabs 0.58 inch thick by laminating a number of thin layers on a calender.

12. The slabs of both Type H material and Compound 384-578 weighed 4-1/2 pounds per square foot. The slabs were cemented to the steel bars, and to each other when more than one layer was applied, by means of an epoxy resin, Chemlock 301, which hardene at room temperature. One to four layers of either one of the two damping compounds were applied to the 1-3/4 inch thick steelbars, and one or two layers to the 3/4 inch thick bars. The purpose of the multilayer treatments was to study the effect of treatment thickness on damping, within the maximum weight limit for treatments as established by the Bureau. This limit is 25% of the weight of the submarine plates. This limit corresponded to the

to the weight of four layers of the two damping treatments on 1-3/4 inch thick bars. The limit was slightly exceeded when two layers were applied to 3/4 inch thick bars. The weight ratio in this instance was 0.30.

13. It is not practical to apply damping treatments to both sides of the hull plating of submarines. For this reason, only test assemblies with one-sided application of the damping compounds were tested on the 1-3/4 inch thick steel bars. The 3/4 inch thick plates are located in the interior of the submarine, and thus lend themselves to two-sided applications. Consequently, both one-sided and two-sided treatments were tested on the 3/4-inch thick steel bars.

TESTING PROCEDURES

14. The felt treatments, Treatments 200 and 218, were tested over the temperature range of 35° to 120°F. The treated bars were placed in a chamber where the temperature was maintained within ±1°F of the desired level. The bars were conditioned at each temperature for a minimum of two hours before measuring damping. An initial constraining pressure of 40 psi was applied to the treatment at room temperatures prior to these measurements. The treatment was not disturbed in the course of the tests, as the temperature was varied. The homogeneous treatments were conditioned for a minimum of 16 hours.

15. Appendix 4 is a diagram of the instrument arrangement used for measuring damping. The measuring procedure was described in detail in Report 94-36. Briefly, it was as follows: the test bar with the applied treatment was suspended horizontally from an edge of the bar at two attachment points by means of a light rope. An electromagnetic oscillator, which served to excite vibrations in the test assembly, was connected to one end of the bar, and an accelerometer to the other end. The frequency of the oscillator was gradually increased until

the response of the accelerometer indicated a resonance for the bar assembly. The drive to the oscillator was then shut off by means of a relay, and the decaying vibration, as detected by the accelerometer, was displayed on the Memoscope. Damping, C, expressed as percent of the critical damping C_o, was calculated according to the following formula:

$$\% \frac{C}{C_o} = \frac{K \tan A}{TF}$$

where K = a constant which includes calibration factors of the instruments used.

A = attenuation angle of the logarithm of the amplitude signal on the Memoscope.

T = sweep time of the Memoscope, in seconds.

F = vibration frequency of the test bar, in cycles/seconds.

16. Damping measurements were made only over the frequency range between about 50 and 3000 cps.

RESULTS AND DISCUSSION

17. The results of the tests are tabulated in Appendices 1, 2 and 5. Selected data are graphed in Appendices 6, 7 and 8. The damping values over the frequency band of 50 to 2000 cps were averaged. These averages are referred to hereunder as "average damping".

18. Treatment 200, which utilized chromated felt, exhibited a sharp maximum damping at 75° to 85°F. This was evident from the values for average damping as well as from the width of the frequency range at which damping was equal to or greater than 5% $\frac{C}{C_o}$, appendices 5 and 6. By contrast, the average dampings for Treatment 218, which utilized nontreated felt, remained practically constant between 35° and 120°F, and damping was substantially lower than for Treatment 200, Appendix 6. Indeed, it was only slightly above the damping level obtained with untreated steel bars.

19. It is concluded from these data that the pronounced temperature-sensitivity exhibited by damping treatments based on constrained chromated felt is due to the additives to the felt rather than to the felt proper. This temperature sensitivity is presumably related to marked changes in the viscosities of the additives with temperature. The chromated felt is soft and sticky above about 100°F, but appreciably stiffer, and nonsticky below 50°F. It is believed that satisfactory damping probably can be obtained with treated felt over the temperature interval of 35° to 120°F.by the substitution of suitable additives for the compounds which are now incorporated into the chromated felt. Such additives must show only small variations in their viscosities at temperatures between 35° and 120°F.

20. The two unconstrained treatments were tested only at 85°F. Average dampings of these treatments and maximum damping between 50 and 3000 cps were approximately proportional to the number of treatment layers applied, and to the weight ratios of treatment to steel, Appendices 1 and 2. These relations held in the case of the one-sided applications. Lower damping, however, was obtained when one treatment layer was applied to each of the two faces of the steel bar, than when two layers were applied to one face of the steel bar. This is indicated by the data for Treatments 213 and 214, and for Treatments 216 and 217, Appendix 1.

21. In the case of 3/4 inch thick steel bars, the chromated felt treatment 200 with a weight ratio of only 0.23 was superior even to the unconstrained treatments 213, 214, 216 and 217, with a weight ratio of 0.30. This superiority manifested itself in average damping, and in the width of the frequency band over which damping was equal to or greater than 5% of critical damping, as indicated by the data of Appendix 1.

22. The superiority of the constrained chromated felt Treatment 200 over the unconstrained treatments manifested itself also in the frequency range at which high damping occurred. The principal noise in submarines is presumably of low frequencies. Damping at low frequencies would be more desirable than damping at high frequencies. The damping obtained with Treatment 200 in the low frequency band between 50 and 500 cps ranged from 6% to 9% of critical as indicated in Appendix 7. The corresponding damping obtained with Treatment 214, the best of the unconstrained treatments, was only 0.3% to 2.5% of critical. Damping equal to or greater than 5% of critical was obtained with this treatment only at the higher frequency range of 650 to 1800 cps.

23. The superiority of the constrained chromated felt treatment over the unconstrained treatments is also evident in the case of the 1-3/4 inch thick steel bars, as indicated by the data of Appendix 2, and the graphs of Appendix 8. On these graphs were plotted the results which were obtained with Treatment 198 and with the two best unconstrained treatments applied to 1-3/4 inch thick steel bars. The superiority of the constrained felt treatment is indicated by its higher average damping, and by its higher damping, from 5% to 7% of critical, in the low frequency range between 50 and 300 cps. The damping of Treatment 207 in this frequency range was only from 0.3% to 2.5%.

24. Previous tests, wherein Type H treatment was applied to 3/8 inch thick steel discs, showed maximum average damping at 90°F in the temperature interval between 30° and 90°F, and for frequencies up to about 2000 cps, Report No. 94-31. Average damping at 90°F, a temperature only slightly above the temperature at which this treatment was tested in the present work, was approximately twice as large as at 50° and 30°F. In view of this behavior, it was concluded that Type H treatment was not likely to yield satisfactory damping of thick steel plates throughout the temperature range of 35° to 120°F. Consequently, no damping tests were conducted with this treatment at temperatures other than 85°F.

25. It was noted that the unconstrained polyvinyl acetate treatments tended to sag when the temperature was raised to 120°F. Manifestly, this material was not suitable for service at moderately high temperatures.

CONCLUSIONS

26. The results obtained in this work led to the following conclusions:

a. The pronounced effect of temperature on the damping behavior of treatments consisting of a constrained chromated felt and a constraining aluminum layer is due to the behavior of the compounds incorporated into the felt, or deposited on its surface, rather than to the felt proper.

b. Unconstrained treatments prepared from either Type H compound, a nitrile rubber vulcanizate, or from stock 384-587, a compound of a modified polyvinyl acetate, are less satisfactory for damping thick submarine steel plates than constrained, chromated-felt treatments.

FUTURE WORK

27. It is clear from the work performed that in order for felt to be useful in constrained-layer damping treatments, it must be impregnated with some viscoelastic material which has lower temperature sensitivity than the materials now used in chromated felt. It is planned to investigate impregnates made from materials such as silicone rubber whose properties are known to be relatively insensitive to temperature within the range of 35° to 120°F. It is also planned to investigate the use of solid viscoelastic materials for constrained layers.

28. An attempt will be made to correlate the damping efficiency of the constrained layer with its dynamic spring rate and loss factor. If this can be done, it will greatly facilitate the evaluation of candidate materials for the constrained layer.

PERSONNEL

Bureau of Ships Project Engineer: W. Marcellino

Work performed by: Frank Caggegi, Technologist
D. L. Phillips, Physicist

Report prepared by: J. Oser, Technologist

Supervised by: R. R. James, Supervisory Technologist

Approved by: R. E. Morris, Head, Rubber Laboratory

APPENDICES

DESCRIPTION OF DAMPING TREATMENTS AND DAMPING OF 68 x 4 x 3/4

Treatment No.	Damping Material	Mode of Treatment Application	Nominal Weight Ratio of Treatment to Steel
200	1/4 inch chromated felt	Constrained felt and 1/2 inch thick aluminum constraining layer applied to one side of steel bar. Initial constraining pressure - 40 psi	0.23
218	1/4 inch nontreated felt	Constrained felt and 1/2 inch thick aluminum constraining layer applied to one side of steel bar. Initial constraining pressure - 40 psi	0.23
212	Type H*	1 layer on one side of steel bar	0.15
213	Type H	2 layers, one on each side of steel bar	0.30
214	Type H	2 layers on one side of steel bar	0.30
215	384-578**	1 layer on one side of steel bar	0.15
216	384-578	2 layers, one on each side of steel bar	0.30
217	384-578	2 layers on one side of steel bar	0.30

* Unconstrained treatment. Thickness of each applied layer was 0.63 inch.
** Unconstrained treatment. Thickness of each applied layer was 0.58 inch.

EATMENTS AND DAMPING OF 68 x 4 x 3/4 INCH STEEL BARS AT 85°F

t Application	Nominal Weight Ratio of Treatment to Steel	Average Damping Over Frequency Band of 50 - 2000 cps $\% \frac{C}{C_o}$	Frequency Range Over Which Damping was 5% $\frac{C}{C_o}$ or Greater cps	Maximum Damping $\% \frac{C}{C_o}$
inch thick aluminum ed to one side of training pressure -	0.23	6.9	50 - 1700	8.9
inch thick aluminum ed to one side of training pressure -	0.23	0.7	none	1.8
eel bar	0.15	1.4	none	2.9
le of steel bar	0.30	2.0	1650 - 2250	5.5
steel bar	0.30	4.2	600 - 1750	9.6
eel bar	0.15	0.7	none	1.1
le of steel bar	0.30	1.2	none	2.2
steel bar	0.30	1.6	2050	5.0

ed layer was 0.63 inch.
ed layer was 0.58 inch.

2

1

DESCRIPTION OF DAMPING TREATMENTS AND DAMPING OF 96 x 6 x 1-3/4 INCH

Treatment No.	Damping Material	Mode of Treatment Application	Nominal Weight Ratio of Treatment to Steel
198	1/4 inch chromated felt	Constrained felt and 1-1/4 inch thick aluminum constraining layer applied to one side of steel bar. Initial constraining pressure - 40 psi	0.25
204	Type H*	1 layer on one side of steel bar	0.065
205	Type H	2 layers on one side of steel bar	0.13
206	Type H	3 layers on one side of steel bar	0.19
207	Type H	4 layers on one side of steel bar	0.26
208	384 - 578**	1 layer on one side of steel bar	0.065
209	384 - 578	2 layers on one side of steel bar	0.13
210	384 - 578	3 layers on one side of steel bar	0.19
211	384 - 578	4 layers on one side of steel bar	0.26

* Unconstrained treatment. Thickness of each applied layer was 0.63 inch.
** Unconstrained treatment. Thickness of each applied layer was 0.58 inch.

ENTS AND DAMPING OF 96 x 6 x 1-3/4 INCH STEEL BARS AT 85°F

pplication	Nominal Weight Ratio of Treatment to Steel	Average Damping Over Frequency Band of 50 - 2000 cps % $\frac{C}{C_o}$	Frequency Range Over Which Damping was 5% $\frac{C}{C_o}$ or Greater cps	Maximum Damping % $\frac{C}{C_o}$
l/4 inch thick ayer applied to one :ial constraining	0.25	4.7	50 - 550	8.9
steel bar	0.065	0.8	none	2.5
steel bar	0.13	1.8	none	3.9
steel bar	0.19	2.5	700 - 1000	7.5
steel bar	0.26	3.3	400 - 850	10.4
steel bar	0.065	0.3	none	0.9
steel bar	0.13	0.6	none	1.4
steel bar	0.19	1.0	none	2.7
steel bar	0.26	1.8	none	3.3

ed layer was 0.63 inch.
ed layer was 0.58 inch.

2

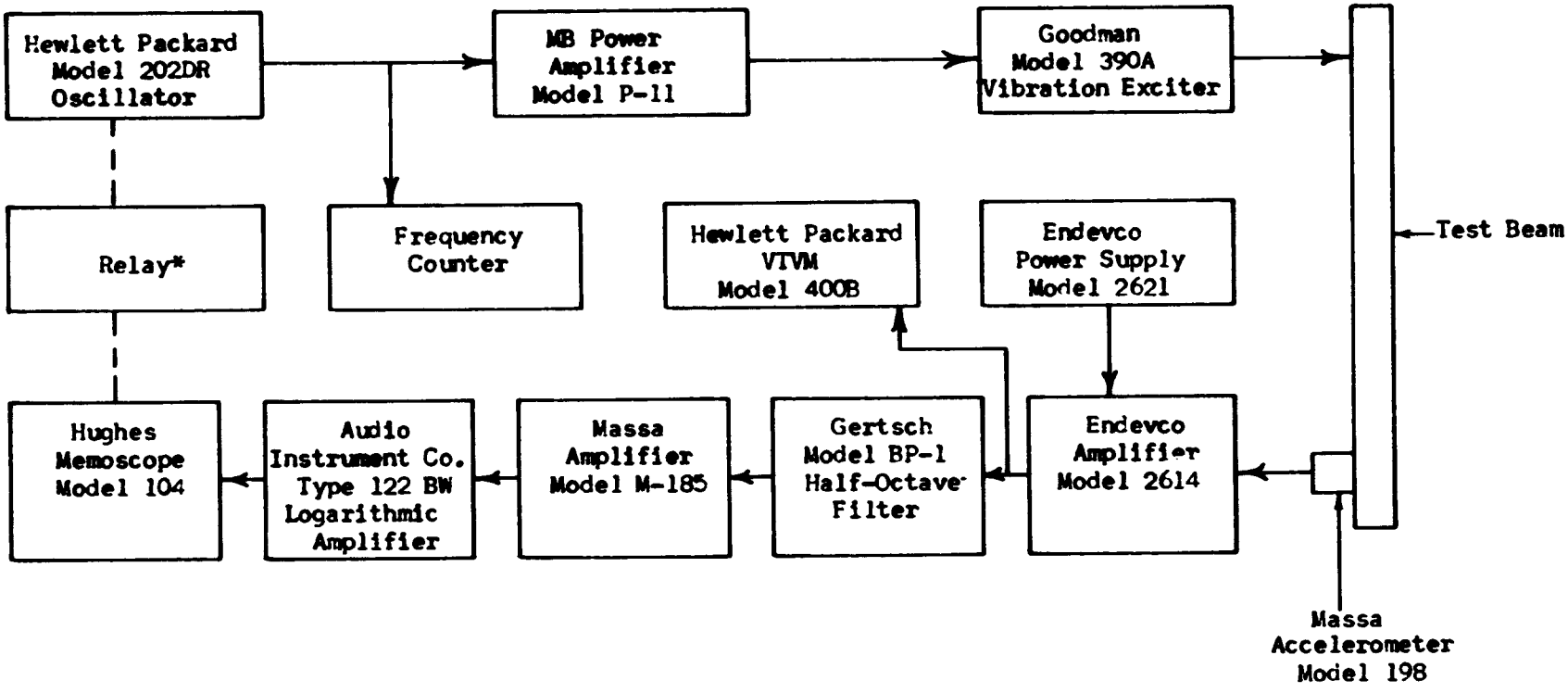
RECIPES FOR UNCONSTRAINED DAMPING TREATMENTS

Type H Compound	
Paracril 18-80	100
Atomite	100
HiSil 233	10
Thermoguard H	15
Pelletex	2
Protox 166	5
Stearic acid	2
Chlorowax 70	50
Neozone D	1
Thionex	0.5
Dyphos	2
Sulfur	2

Compound 384-578	
Gelva M-7-V100R (modified polyvinyl acetate)	100
Graphite, No. 2 Flake	120
Aroclor 1248	100
Thermoguard H	5
KLA (lubricating agent)	1

CURE: 10 minutes at 320°F

SCHEMATIC LAYOUT OF INSTRUMENTATION USED TO EVALUATE DAMPING TREATMENTS



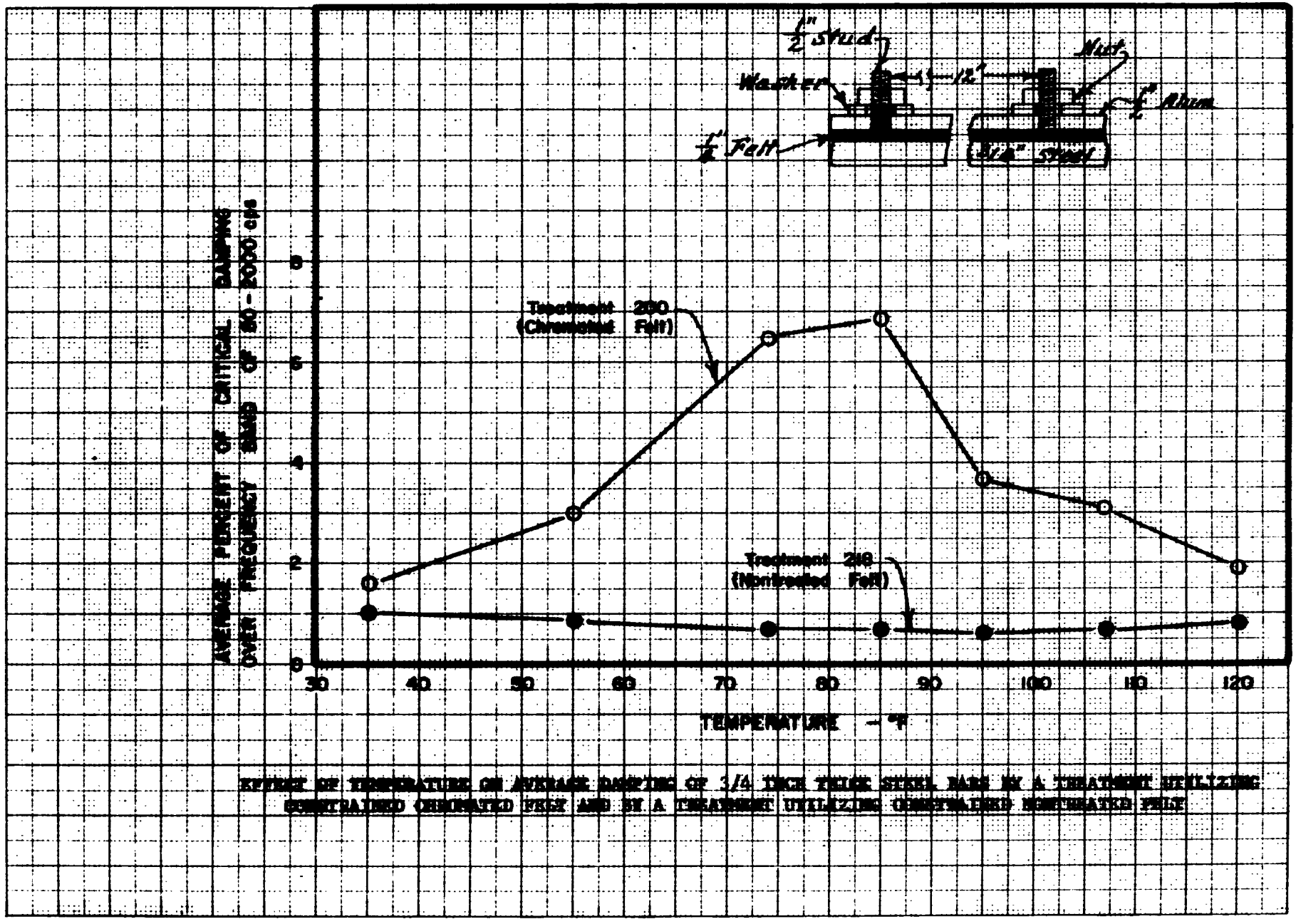
* Relay interrupts output of oscillator and simultaneously triggers scope.

EFFECT OF TEMPERATURE ON DAMPING OF 3/4 INCH THICK STEEL BARS BY A TREATMENT UTILIZING CHROMATED FELT AND BY A TREATMENT UTILIZING NONTREATED FELT

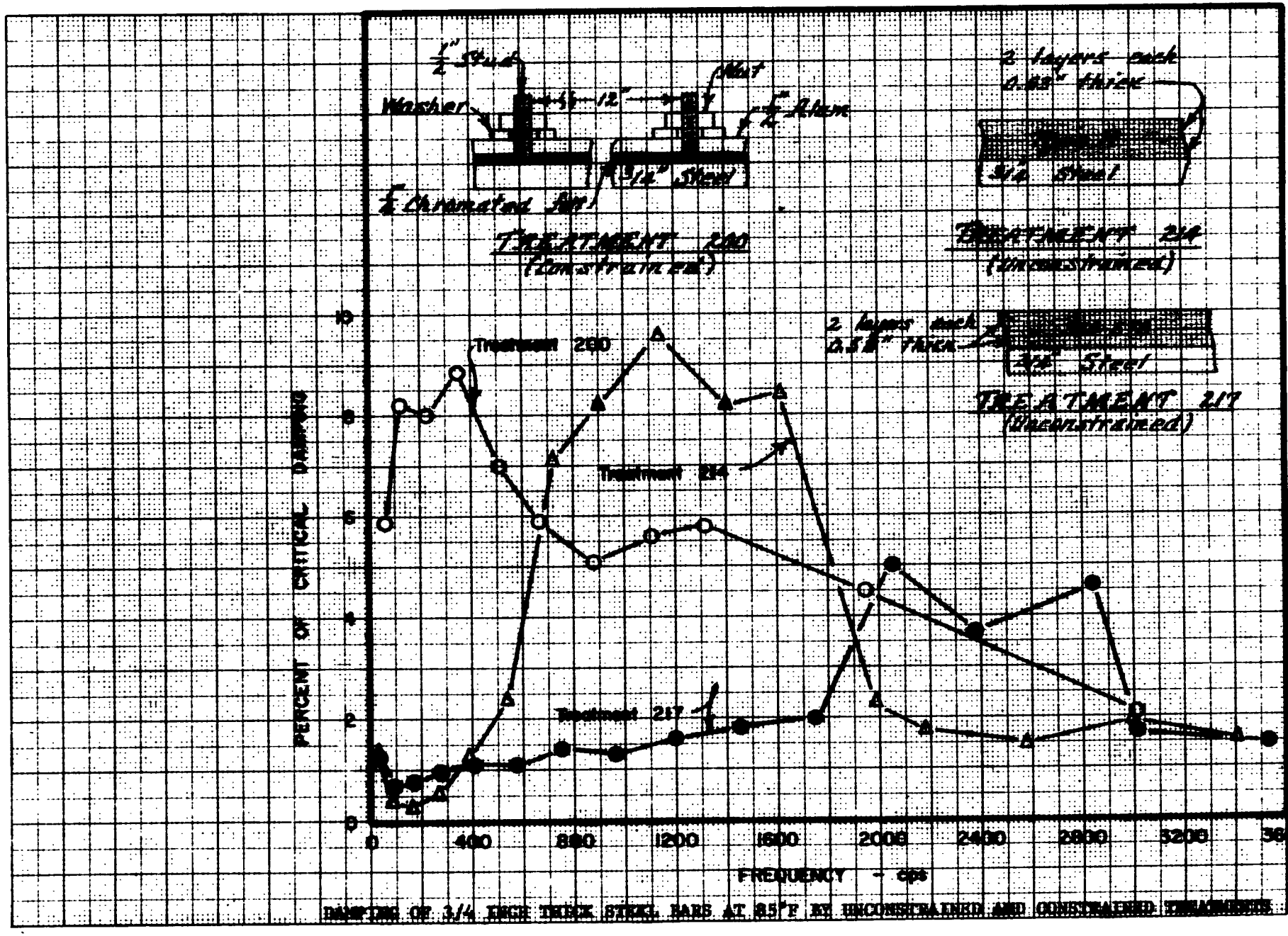
Temperature °F	Average Damping Over the Frequency Band of 50 - 2000 cps, % $\frac{C}{C_o}$		Frequency Range Over Which Damping of Treatment 200 was 5% $\frac{C}{C_o}$ or Greater** cps
	Treatment 200* Constrained Chromated Felt	Treatment 218* Constrained Nontreated Felt	
35	1.6	1.0	none
55	3.0	0.9	1400 - 1750
74	6.5	0.7	50 - 1250
85	6.9	0.7	50 - 1650
95	3.7	0.6	50 - 150
107	3.1	0.7	50
120	1.9	0.8	none

* Initial constraining pressure was 40 psi.

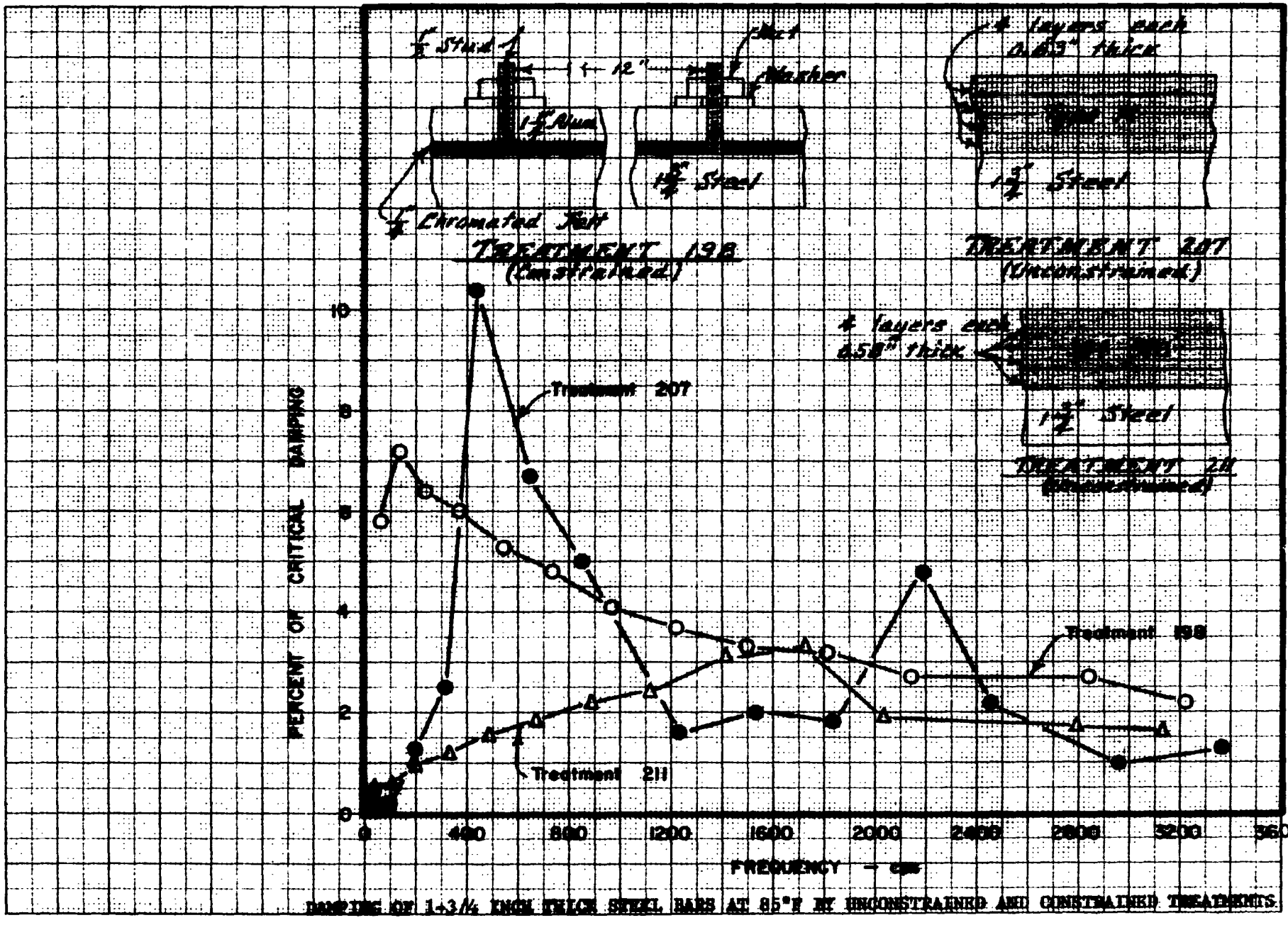
** Damping by Treatment 208 was below 5% $\frac{C}{C_o}$ at all temperatures and frequencies surveyed, except for a sharp peak at 35°F which occurred at a frequency of 2419 cps. Damping in this instance was 7.9% $\frac{C}{C_o}$.



EFFECT OF TEMPERATURE ON AVERAGE DAMPING OF 3/4 INCH THICK STEEL BARS BY A TREATMENT UTILIZING CHROMATED FELT AND BY A TREATMENT UTILIZING UNCHROMATED NONTREATED FELT



DAMPING OF 3/4 INCH THICK STEEL BARS AT 85°F BY UNCONSTRAINED AND CONSTRAINED TREATMENTS



DAMPING OF 1+3/4 INCH THICK STEEL BARS AT 85°F BY UNCONSTRAINED AND CONSTRAINED TREATMENTS.

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Project No. S-F013-13-01, Task No. 908, Ident. No. 1-0908-1

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Unconstrained damping treatments made from a nitrile rubber vulcanizate and from modified polyvinyl acetate were found to be inferior to constrained chromated felt for damping steel bars of 3/4 inch and 1-3/4 inch thickness.

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